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## **A high-intensity jump-based aquatic exercise program improves bone mineral density and functional fitness in postmenopausal women**

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## **Abstract**

The aim of this study was to verify the effects of a high-intensity jump-based aquatic exercise program (HIIAE) on bone mass and functional fitness in postmenopausal women.

**Methods:** We randomly assigned 25 women ( $65 \pm 7$  years) into two groups: Training group (T,  $n=15$ ) and Untrained group (Un,  $n=10$ ). The T group was submitted to 24 weeks of a HIIAE program, where each session lasted for 30 minutes. The following parameters were assessed before and 6 months following the intervention: bone and physical fitness; lumbar spine (LS), total femur (TF) and whole body (WB) bone mineral density (BMD); as well as agility (Timed up-and-go, TUG), and leg strength (chair stand test, CS) **Results:** We observed a significant increase ( $p<0,01$ ) in LS, (Un:  $-0.88 \pm 3.55$ , T:  $3.71 \pm 3.68$ ; %), TF (Un:  $-1.38 \pm 17.76$ , T:  $6.52 \pm 2.71$ ; %) and WB (Un:  $2.09 \pm 3.17$ , T:  $3.23 \pm 4.18$ ) BMD in the T group. Regarding functional fitness, the T group showed improvements in both TUG (before:  $6.86 \pm 1.24$  versus after:  $6.22 \pm 1.13$  seconds,  $p< 0.05$ ) and CS (before:  $16 \pm 4$  versus after:  $19 \pm 5$  repetitions,  $p> 0.05$ ) tests when compared to the U group's TUG (Before:  $5 \pm 1$ , after:  $6 \pm 1$  seconds;  $p< 0.05$ ) and CS (Before:  $20 \pm 2$ , After:  $19 \pm 2$  repetitions;  $p> 0.05$ ) scores. **Conclusion:** Our data suggest that a high-intensity, jump-based interval aquatic exercise program is able to improve bone mineral density and functional fitness parameters in postmenopausal women.

**Keywords:** elderly, HIIT, bone mineral density, aquatic exercise

## **Introduction**

Hormonal changes resulting from the menopause contribute to a state of functional decline, body composition changes, impaired bone metabolism and an increased risk of chronic disease development in women [1-2]. Osteoporosis is a whole body metabolic bone disease which affects almost 200 million people worldwide [3]. Conceptually, it is characterized by substantial loss of bone mass and a decline in bone tissue microarchitecture, which damages the bone's resistance and quality. This renders the individual more susceptible to fractures and, consequently, chronic pain, functional disability and compromised quality of life [4].

Among possible treatments suggested, engaging in regular physical exercise has been considered as an efficient non-pharmacological strategy to maintain [5] or increase [6] bone mineral density. As bone has been classified as a dynamic tissue, regular physical exercise affects bone tissue positively by promoting adaptations through various stimuli, mainly mechanical, which contribute to bone formation [7]. Thereby, resistance and impact-based physical exercise have been highlighted as major non-pharmacological strategies in the treatment of osteoporosis, influencing directly the preservation or improvement of bone mass and functional fitness [8-9]

Even though the effects of the mechanical stimuli resulting from physical exercises on bone tissue are quite clear, there are still doubts about the effectiveness of aquatic exercises on improving bone mineral density in postmenopausal women. Performing motor activities inside an aquatic environment is made easier due to flotation and the inertia of the water, which decreases the mechanical action of friction with the ground on bone tissue [8]. Alternatively, the resistance promoted by the water during movements may increase the muscular demand on the body segments recruited, promoting a higher osteogenic effect [10-11].

There are few studies [10, 12-15] available which utilized an aquatic environment as a tool to improve bone mass. Therefore, the aim of this study was to assess the effects of an aquatic jump-based physical training program on the bone mineral density and the functional fitness of menopausal women.

## **Methods**

### **Participants**

We recruited twenty five elderly women (aged 57-75 years) from the city of Natal, Brazil. We also searched for an aquatic fitness center as a possible venue to perform the experiment. We randomly assigned the subjects into two different groups: Training (T, n =

15) and Untrained (Un, n = 10). All participants were subjected to clinical examination and answered questionnaires regarding their medical history before being included in our study. Participants included in the study were women, 55 years of age or older, who were able to train 3 times per week during the 24 weeks of the exercise protocol.

Exclusion criteria included: participating in a regular and structured physical activity program for 3 months prior to experimentation; recent hospitalization; motor deficiency; symptomatic cardiorespiratory disease; non-controlled hypertension or metabolic syndrome; severe renal or hepatic disease; cognitive impairment or debilitating conditions; marked obesity with inability to exercise; recent bone fracture (during the past 2 years); and participating in fewer than 90% of the sessions stipulated in the Aquatic training program. Both Un and T groups were instructed to continue with their daily activity routines. However, only subjects in the T group participated in the Aquatic training sessions. Participants were also required to maintain normal dietary intake (monitored by nutrition professional). Participants in the training group were asked not to perform any additional physical activity exercises during the study period. Additionally, all subjects were instructed to refrain from any medication that may affect bone metabolism. All participants read and signed the terms of consent following the Declaration of Helsinki before being included in the study.

### **Water based exercise**

The water-based exercise program consisted of 30-minute sessions three times a week, over a 24 week period. Training sessions were performed on three different and non-consecutive days in each week. The water level was fixed at xiphoid or near xiphoid level, with the temperature at 29°C. Each session was divided into three stages. The first stage consisted of 5 minutes warm-up, comprised of stretching and free movements in the water. The second stage comprised of jump-based (single-leg jump, ankle hops, tuck jumps, jump with hip abduction and adduction) exercises for 20 min, performed as high intensity interval exercise, consisting of 20 bouts for 30 seconds of all-out intensity as identified in previous studies by our group [16]. The intensity, although required to be maximal was self-selected by the subjects, who performed 30 seconds of passive recovery between sets. Intensity was monitored using the rating of perceived exertion. Finally, the third stage consisted of cooling-down/relaxation exercises for 5 minutes, composed of slow walking and stretching.

## **Evaluated parameters**

We evaluated both groups prior and following 24 weeks of training. On the test day, participants were instructed to correctly follow the orientations postulated by the researchers. Body mass index ( $BMI = \text{height}/\text{weight}^2$ ) was assessed, and body fat percentage was calculated according to previous studies [17-18]. We used Dual-energy x-ray absorptiometry (DEXA) to scan lumbar spine (L1-L4), total femur and whole body mineral density. All exams were analyzed by the same researcher using the DEA–DTX 200 Osteometer (MediTech), blind to subject condition.

## **Functional fitness**

Functional fitness evaluation was composed of two tests used in previous studies to assess the physical performance parameters of mobility and balance in older adults [17-18]. We used the chair stand test (CS) test to evaluate lower limb strength, scored by the number of correctly executed stands within 30 seconds. We assessed agility through the time up-and-go test (TUG). The score was considered as the shortest time spent rising from a seated position, walking eight feet, turning back and returning to the seated position.

## **Statistical analysis**

We analyzed comparisons between groups along the time periods using a two-way ANOVA with repeated measures, followed by Bonferroni's post-hoc test. Comparisons between groups concerning relative changes in variables after 24-weeks were performed using unpaired Student's t-test. The Cohen's d approach was used to calculate the effect size. Statistical analyses were performed with GraphPad Prism software (version 4.0, San Diego, CA, USA). Statistical significance was set at  $p < 0.05$ .

## **Results**

During the training period, no participants in either group left the study or presented any injuries as result of the exercise program. Before training, there were no significant differences between the groups for all assessed anthropometrics parameters (Tables 1 and 2).

Table 1. Anthropometrics parameters for both groups before and after 24 weeks.

	Untrained		Trained	
	Before	After	Before	After
Height (m)	1.52 ± 0.06	-----	1.51 ± 0.05	-----
Body weight (kg)	62 ± 13	62 ± 13	69 ± 10	69 ± 11
BMI (kg/m <sup>2</sup> )	27 ± 7	27 ± 6	30 ± 5	30 ± 5
Body fat (%)	25 ± 10	26 ± 9	28 ± 8	29 ± 9
Lean mass (kg)	40 ± 6	41 ± 6	40 ± 9	41 ± 10
Fat mass (kg)	34 ± 4	33 ± 4	38 ± 5	37 ± 5

Values are presented as mean ± standard deviation of Untrained and Trained groups. There were no differences in any of the parameters after the two-way ANOVA with repeated measures, followed by Bonferroni's post-hoc test. BMI: body mass index.

Figure 1 shows the BMD parameters before and after 24 weeks of exercise protocol.

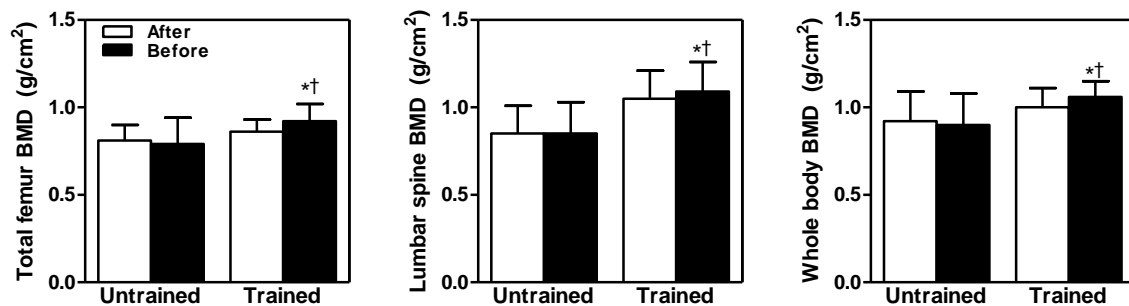


Figure 1. Levels of total femur, lumbar spine and whole body bone mineral density (BMD) before and after the 24-week follow-up.

\*p < .001 before versus after.

†p < .01 Trained versus Untrained group.

The T group did not present significant ( $p > 0.05$ ) reductions in total femur (before:  $0.881 \pm 0.009$  versus after:  $0.790 \pm 0.15$  g/cm<sup>2</sup>), lumbar spine (before:  $0.850 \pm 0.016$  versus after:  $0.850 \pm 0.018$  g/cm<sup>2</sup>) and whole body (before:  $0.920 \pm 0.017$  versus after:  $0.900 \pm 0.018$  g/cm<sup>2</sup>) BMD. However, differences ( $p < 0.01$ ) were found in the hip (before:  $0.860 \pm 0.070$  versus after:  $1.040 \pm 0.100$  g/cm<sup>2</sup>), lumbar spine (before:  $1.050 \pm 0.016$  versus after:  $1.090 \pm 0.015$  g/cm<sup>2</sup>) and whole body (before:  $1.000 \pm 0.011$  versus after:

1.060 ± 0.009 g/cm<sup>2</sup>) BMD when compared to the Un group. Similar results were found at % change in all BMD parameters as showed in table 2.

Table 2. Percent change and effect size after 24 weeks.

Parameters	Untrained		Trained	
	% Change	Cohen's d	% Change	Cohen's d
<i>Body composition</i>				
Body weight (kg)	0.09 ± 1.44	0.009	0.23 ± 2.40	0.024
BMI (kg/m <sup>2</sup> )	0.09 ± 1.44	0.011	0.23 ± 2.40	0.019
Body fat (%)	2.95 ± 2.81	0.066	0.75 ± 8.11	0.084
Lean mass (kg)	3.03 ± 2.67	0.219	0.57 ± 6.83	0.078
Fat mass (kg)	2.24 ± 2.46	0.199	2.07 ± 4.39	0.158
<i>Bone mineral density</i>				
Total femur (g/cm <sup>2</sup> )	-1.38 ± 17.76	0.169	6.52 ± 2.71*	0.850
Lumbar spine (g/cm <sup>2</sup> )	-0.88 ± 3.55	0.176	3.71 ± 3.68*	0.500
Whole body (g/cm <sup>2</sup> )	2.09 ± 3.17	0.098	3.23 ± 4.18*	0.185

Values are presented as mean ± standard deviation in the Untrained and Trained groups.

\*p< .01 trained versus untrained group.

Regarding functional fitness (Figure 2), we observed improvements of -11 ± 4 % on the TUG test (Before: 6.86 ± 1.24, After: 6.22 ± 1.13 seconds, p< 0.05) and 17 ± 3 % on CS test (Before: 16 ± 4, After: 19 ± 5 repetitions, p> 0.05; repetitions) in the T group. We did not observe any changes (p< 0.05) on the TUG test (before: 5 ± 1 versus after: 6 ± 1 seconds) or the CS test (Before: 20 ± 2, After: 19 ± 2 repetitions) in the Un group.



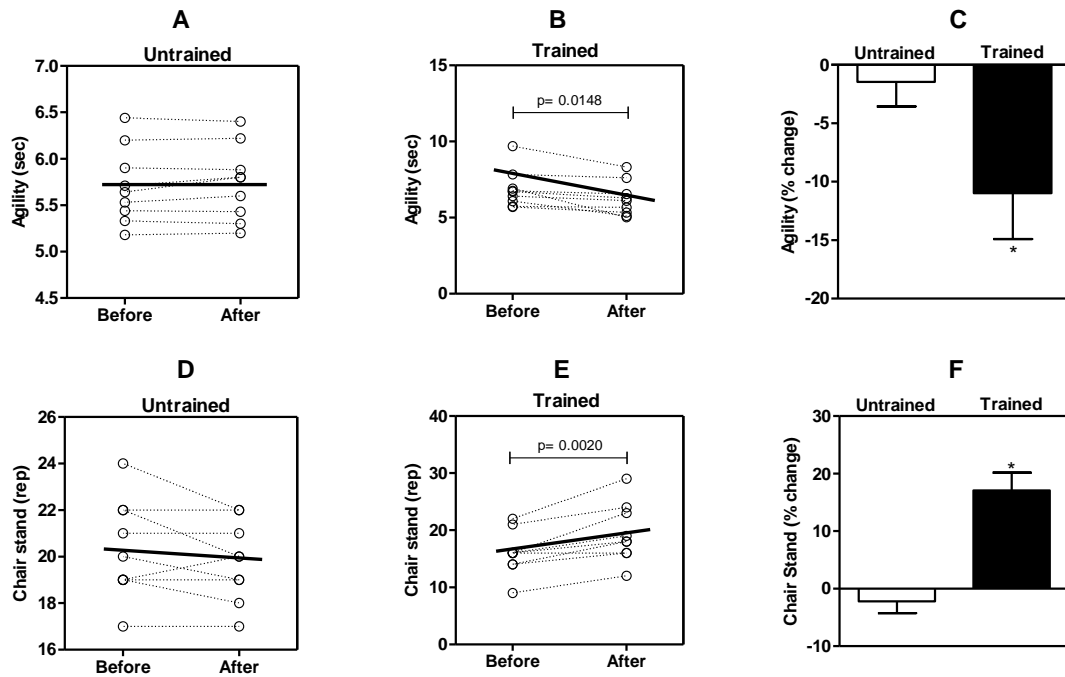


Figure 2. Functional fitness of Untrained and Trained groups before and after the 24-week follow-up of jump based exercise program.

\* $p < .001$  trained versus untrained group.

## Discussion

Since flotation diminishes impact, aquatic exercises are typically classified as exercises of low osteogenic effect. However, the results from this study did not corroborate with this information. In our study, the protocol of all-out, jump-based impact exercises in water resulted in increased BMD and improved functional fitness in postmenopausal women.

Over the lifespan, environmental factors, such as mechanical loading, nutrition, hormonal and genetic factors, may influence body mass [19]. It is estimated, from clinical studies, that genetics correspond for between 60 to 80% of the variance of bone mass during a lifetime [20]. Nonetheless, according to Wolff's law, mechanical stimulus, as well as loading magnitude, is considered as an active osteogenic stimulus [21-22].

Impact or resistance-based physical activities using muscle traction generally result in strain stress, compression, and shear stress when the bone is strained by many different loadings [23]. These loadings via the bone tissue are detected via mechanotransduction, which is the conversion of a mechanical force into a cellular response, generating more complex biochemical reactions in bone cells [24]. However, it should be highlighted that bone formation only occurs if the physical exercise stimulus exceeds a certain threshold, being capable of generating a loading above the usual

everyday standard to which the body has adapted [25]. Indeed, longitudinal studies analyzing the influence of physical exercise on bone mass have demonstrated that active and resisted physical activities can stimulate bone mass in postmenopausal women [26-29].

Similar to our study, Alev and Yurtkuran (2005) evaluated the bone mass of postmenopausal women submitted to moderate exercises, both on the ground (walking) and in aquatic environments (jumping and swaying in the water). In both situations, positive results in bone remodeling were found, following assessment through imaging scans (heel bone ultrasound scan).

Additionally, the hydrodynamic effects of water in increasing resistance to movement, improving muscle and joint effort during walking, jumping or moving body segments in an aquatic environment, are already recognized [30-31]. Some studies suggest [32-33] that, even with the predominance of impact exercises such as jumping, the effect of muscle action still helps to decrease impact on joints during landing on the ground. This may promote a response in bone cells which may stimulate osteogenesis, since muscular contraction stresses the tendon inserted in the bone, creating deformation that can spread through the fluid flow, activating the osteocytes contained in the canaliculi [24].

It is a consensus that muscle mass has a significant role in the acquisition and maintenance of bone structure, and increases in structure may explain the effects on BMD variance – from 6% to 16%, depending on the assessed bone site. Besides increasing bone mineral density, muscular strength development also promotes improvement in motor coordination, postural stabilization, dynamic balance and muscular strength, enabling physical autonomy and improving quality of life [34]. In addition to this, recruiting type II muscular fibers, which happens more often during high-intensity exercises, is more likely to stimulate bone tissue development [35].

Similarly, to the findings of Nolasco et al., 2017, but in contrast to Takeshima et al., 2002 and Colado et al., 2012, the protocol we used in this study did not promote significant changes in body composition parameters. It is possible that this was influenced by the short duration of the training sessions, as well as the lack of any monitoring of the food intake of the participants. However, this exercise program was efficient in improving the muscular strength of the lower limbs as well as agility, and is in agreement with previous studies [17-18, 39-40]. As such, our findings suggest that an aquatic exercise program based on high-intensity jumping may help to maintain body mass and improve muscular strength, both of which are parameters recognized as relevant to bone mass [41]. In addition, the findings also suggest that this type of activity maintains or promotes gains in body mass in elderly women.

In conclusion, we found that a high-intensity jump-based aquatic exercise program was efficient in improving bone mass and functional fitness in postmenopausal women. However, some limitations in the study were present, such as a relatively small sample size of a specific population, which does not allow for further generalizations. Therefore, future research in this area should consider the association between diet/dietary restriction, inflammatory cytokines, as well as assessing functional fitness parameters.

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